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Hanchett

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(54) **METHODS AND APPARATUS FOR A BATTERY AND REGULATING THE TEMPERATURE OF BATTERIES**

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(51) **Int. Cl.**

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H01M 10/613	(2014.01)
H01M 10/6556	(2014.01)
H01M 50/543	(2021.01)

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(58) **Field of Classification Search**

CPC .. H01M 50/54; H01M 50/543; H01M 10/613; H01M 10/6553; H01M 10/6556

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,436,548	A	7/1995	Thomas
5,585,206	A	12/1996	Morris
9,246,169	B2	1/2016	Matsumoto
9,391,326	B2	7/2016	Yamamoto
2004/0038124	A1	2/2004	Hisamitsu
2014/0087237	A1	3/2014	Dhar
2015/0017519	A1	1/2015	Cho

(Continued)

FOREIGN PATENT DOCUMENTS

CN	101499545 A *	8/2009	.... H01M 10/613
JP	2008251306 A *	10/2008	.... H01M 10/613

(Continued)

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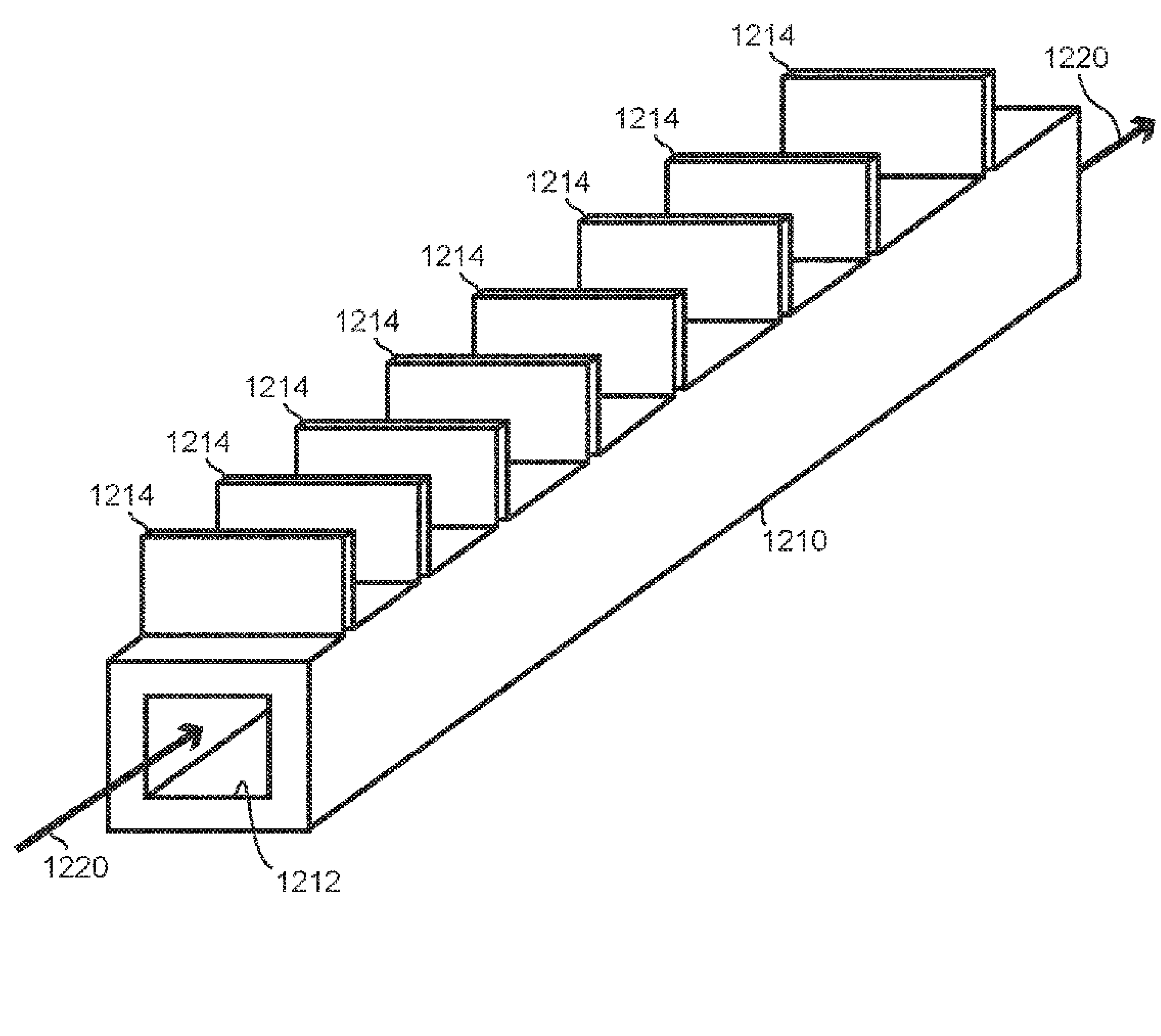
(57) **ABSTRACT**

A battery that includes collectors with tabs that are wide with respect to the area of the collector. The wide tabs present a low electrical and thermal resistance to improve the flow of current and/or heat to and from the collector thereby improving electrical and thermal performance of the battery. The battery further includes terminals with a channel that supports the flow of medium (e.g., liquid) to heat and/or cool the battery. The terminals may include fins or pins to increase the surface area of the terminal to improve thermal transfer to and from the battery and collectors of the battery. The batteries may be formed into a battery module that includes a system for monitoring and regulating the temperature of the batteries of the module.

19 Claims, 7 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2015/0221998	A1*	8/2015	Jin	H01M 10/6551 429/120
2016/0111713	A1	4/2016	Yamazaki	
2017/0194610	A1	7/2017	Tschiggfrei	
2017/0324086	A1	11/2017	Nitta	
2018/0219191	A1	8/2018	Drews	
2018/0241023	A1	8/2018	Lim	

FOREIGN PATENT DOCUMENTS

WO	WO-2012023804	A2 *	2/2012	H01M 10/0413
WO	WO-2017069453	A1 *	4/2017	H01M 10/0413

* cited by examiner

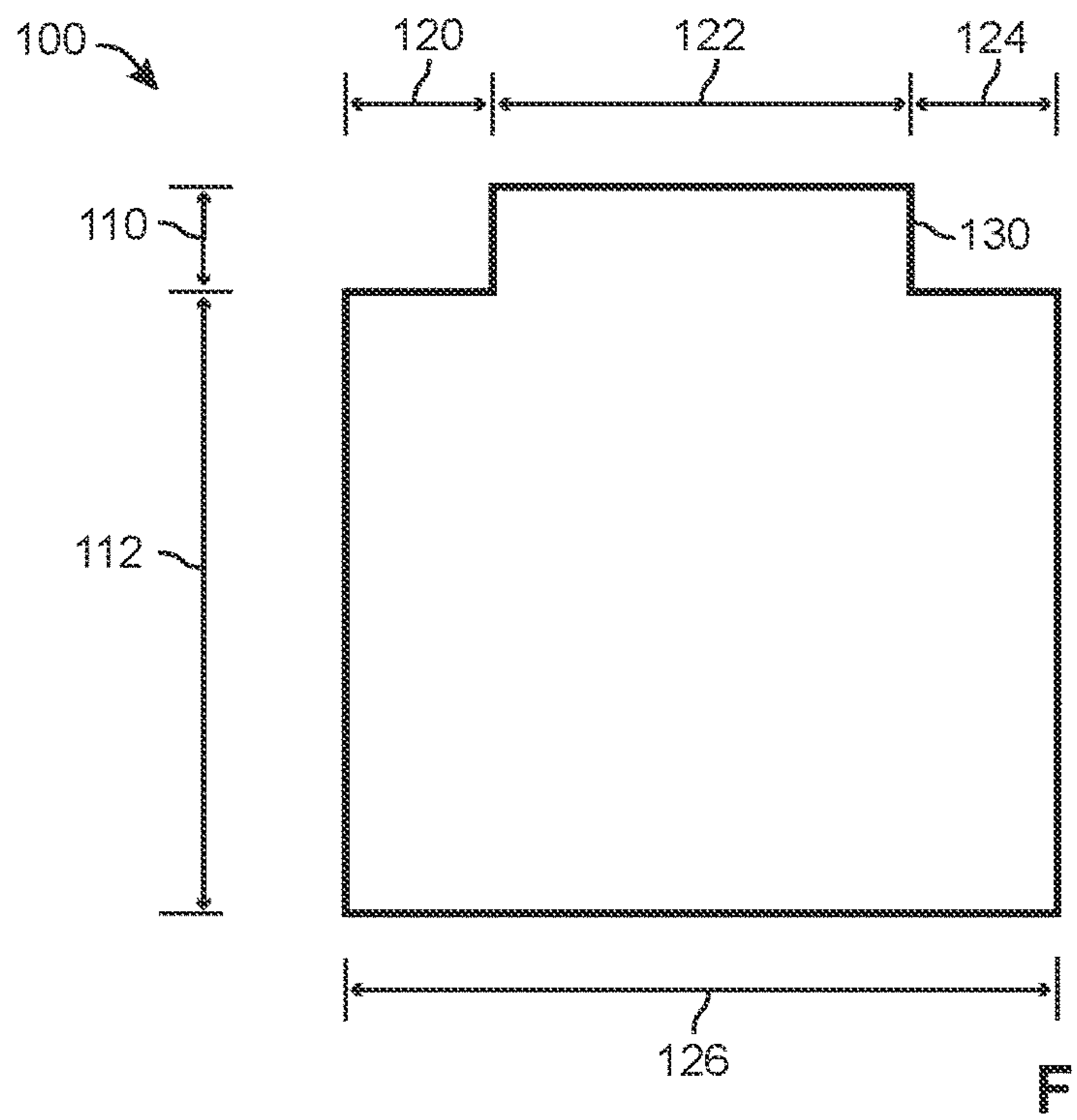


FIG. 1

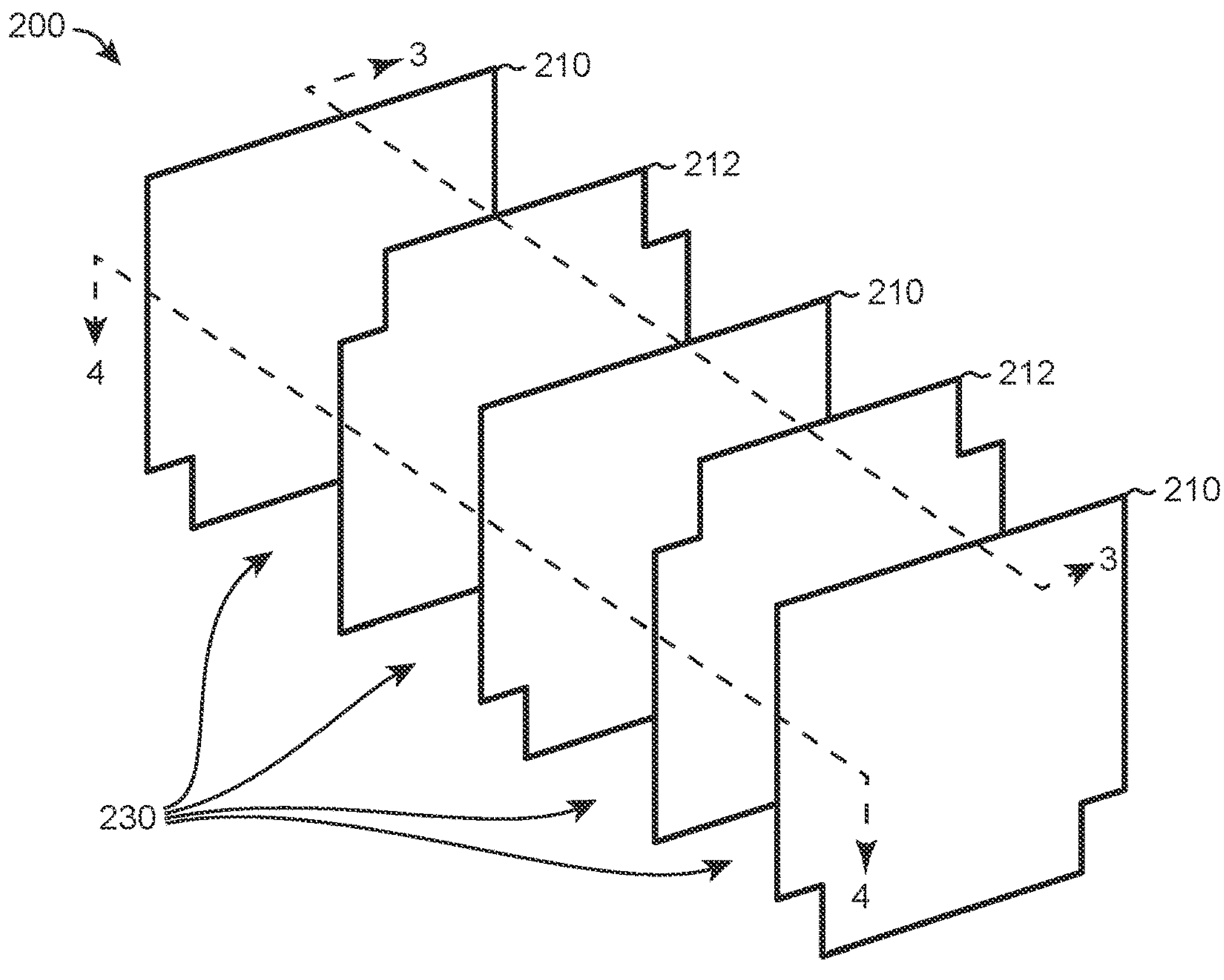


FIG. 2

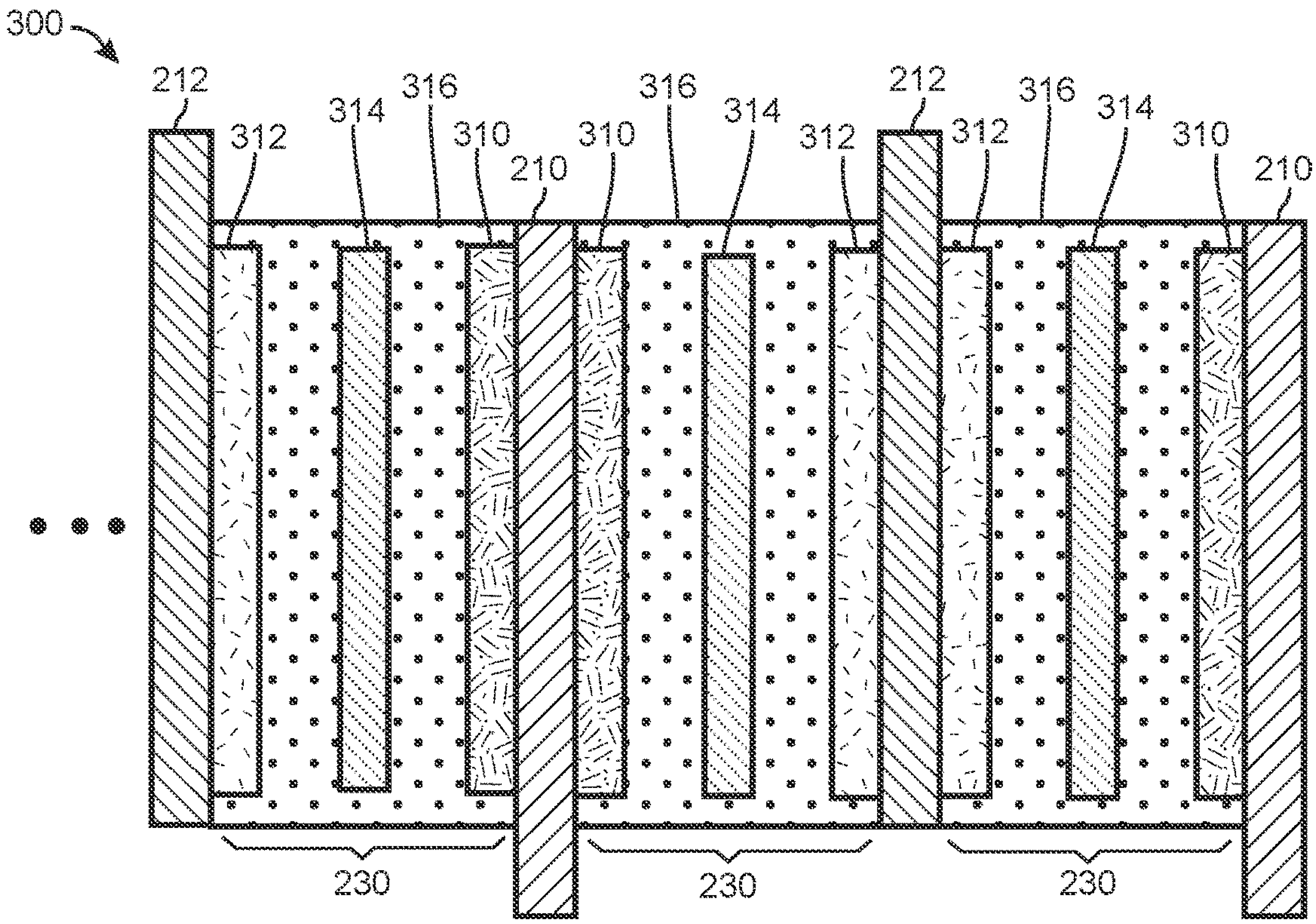

300
212
312
314
316
310
210
310
316
314
312
212
312
316
314
310
210
230
230
230

FIG. 3

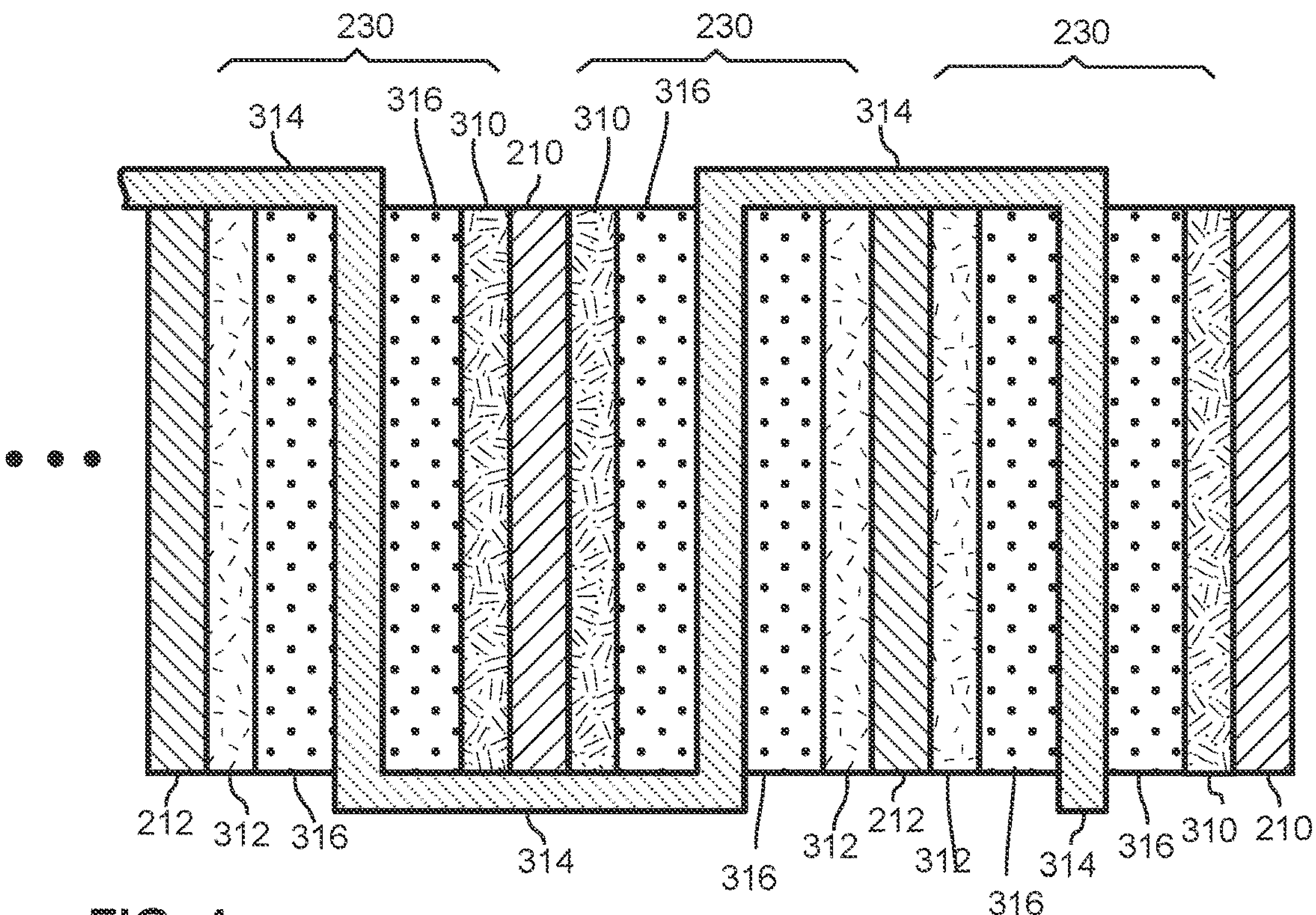

230
230
230
314
316
310
210
310
316
314
212
312
316
314
316
312
212
312
316
314
316
310
210

FIG. 4

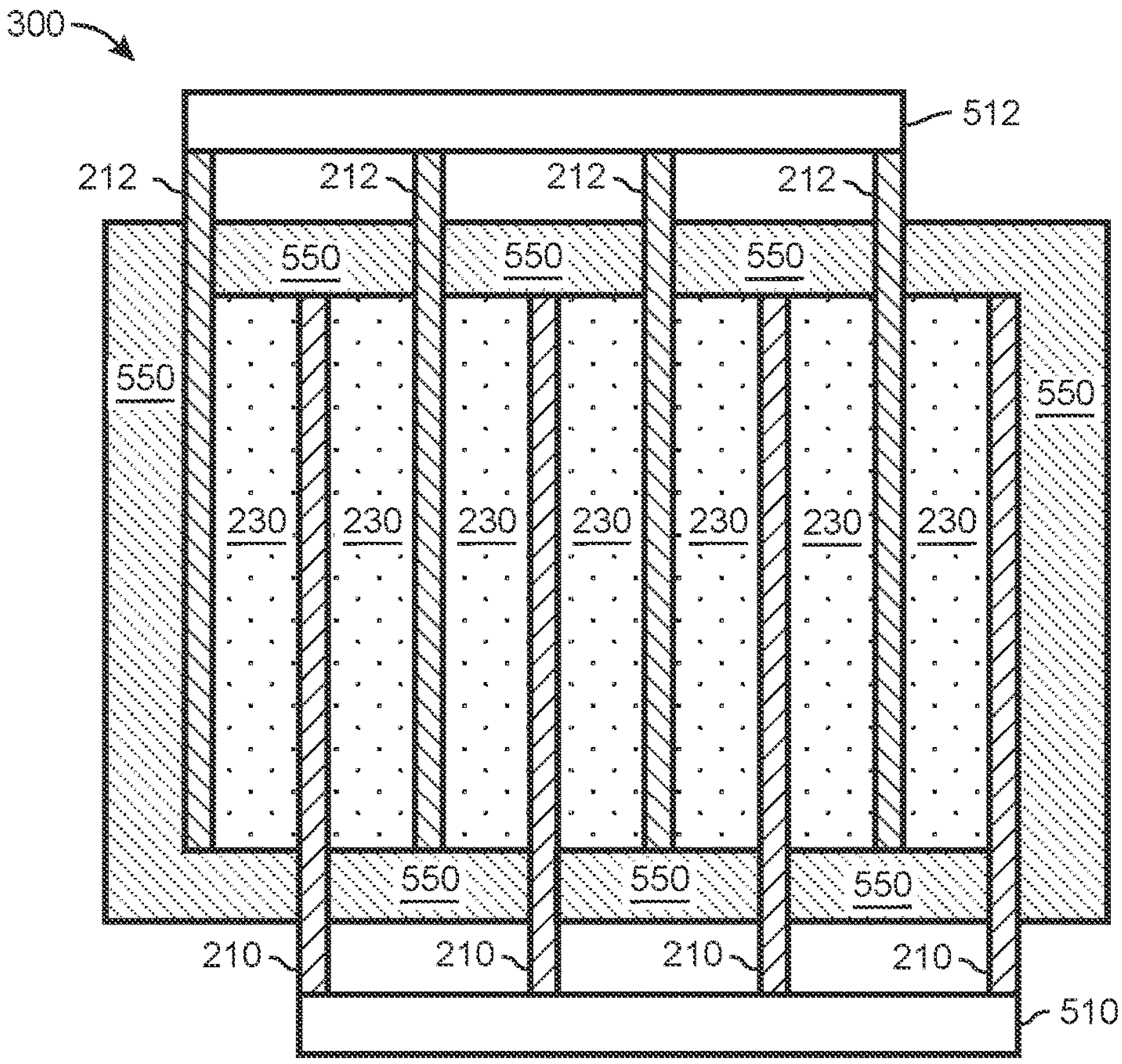

300
512
212
212
212
212
550
550
550
550
550
230
230
230
230
230
230
230
550
550
550
210
210
210
210
510

FIG. 5

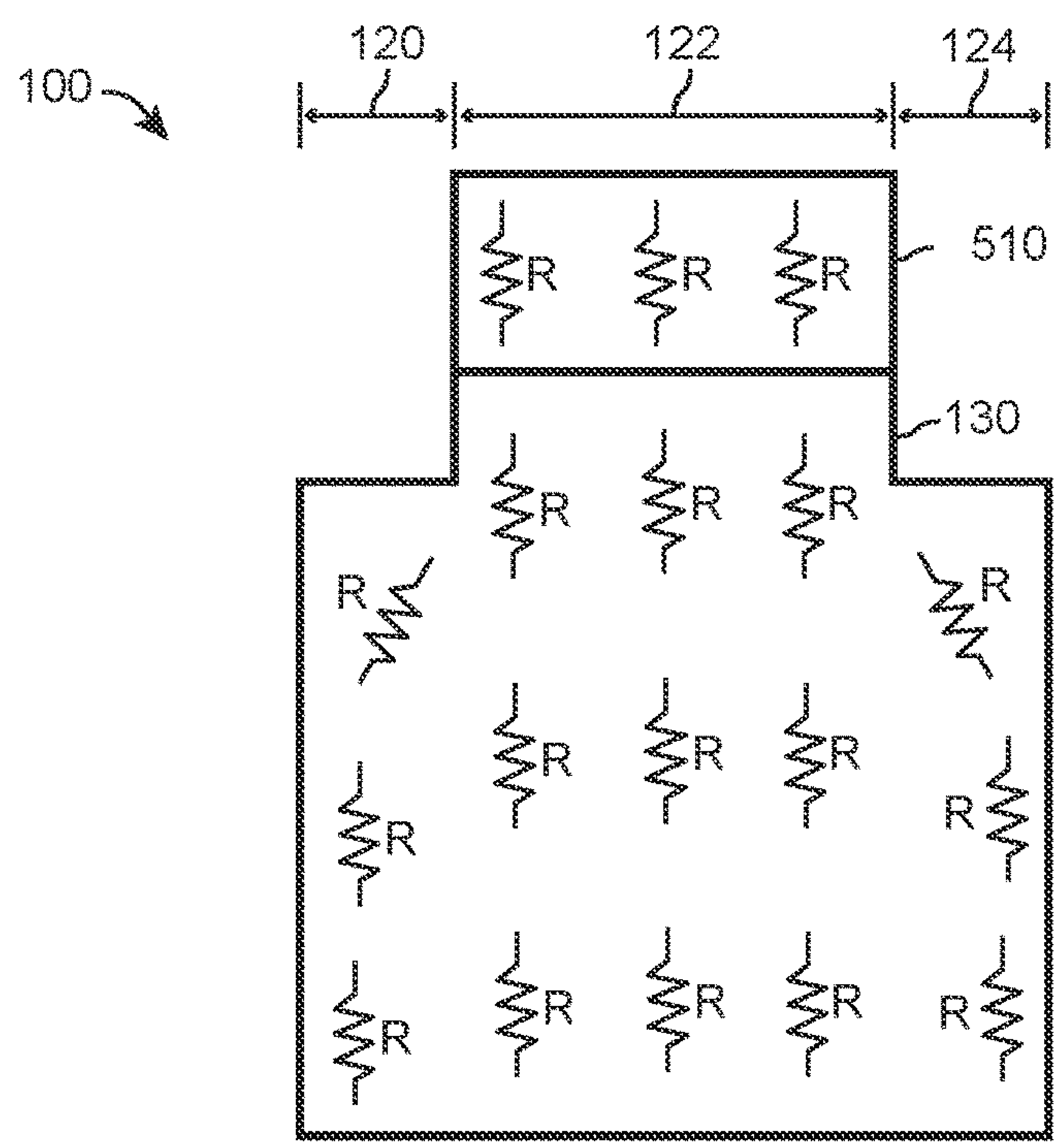

100
120
122
124
510
130
R

FIG. 6

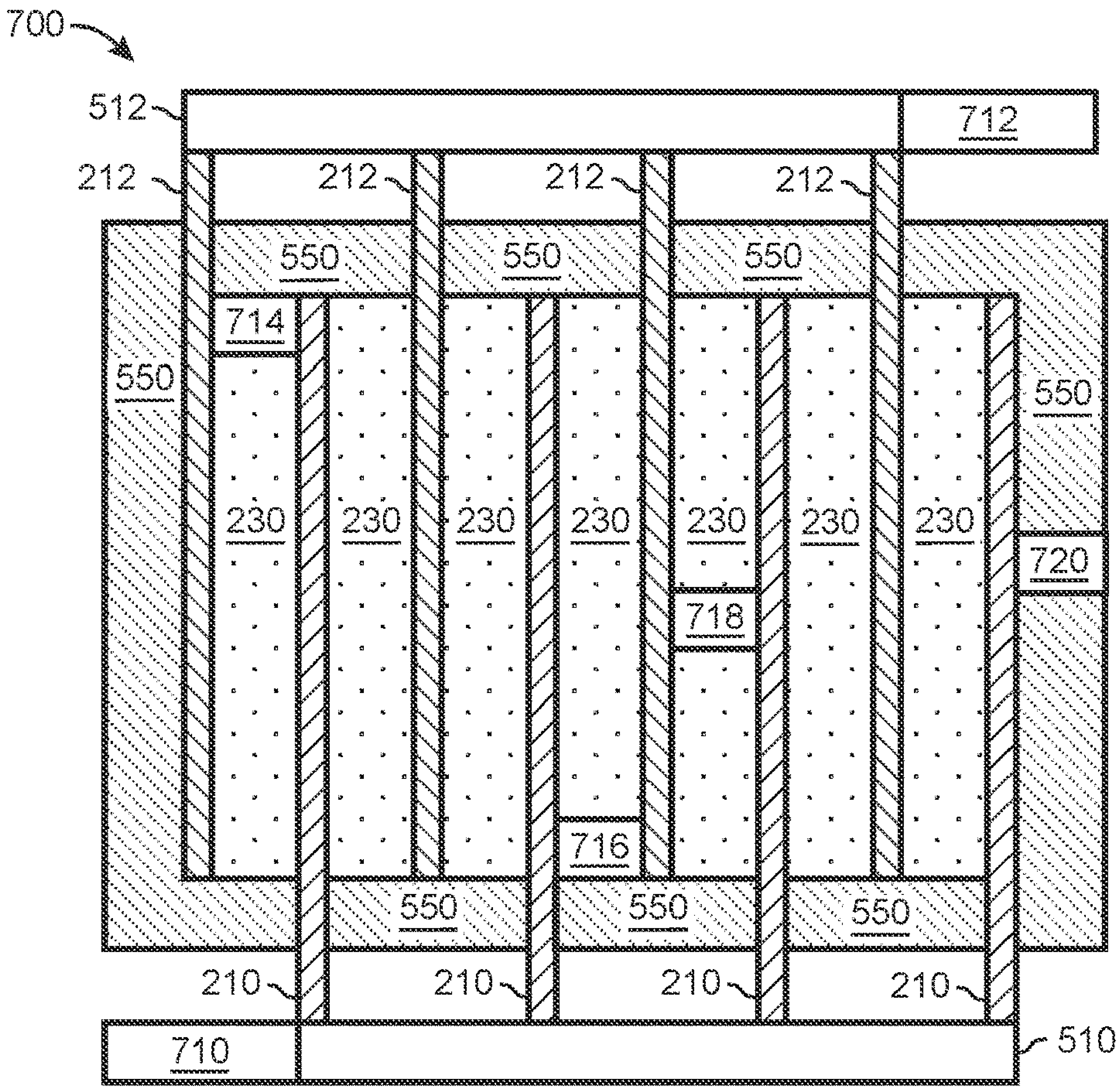

700
512
712
212
212
212
212
550
550
550
550
714
550
230
230
230
230
230
230
230
720
718
716
550
550
550
210
210
210
210
710
510

FIG. 7

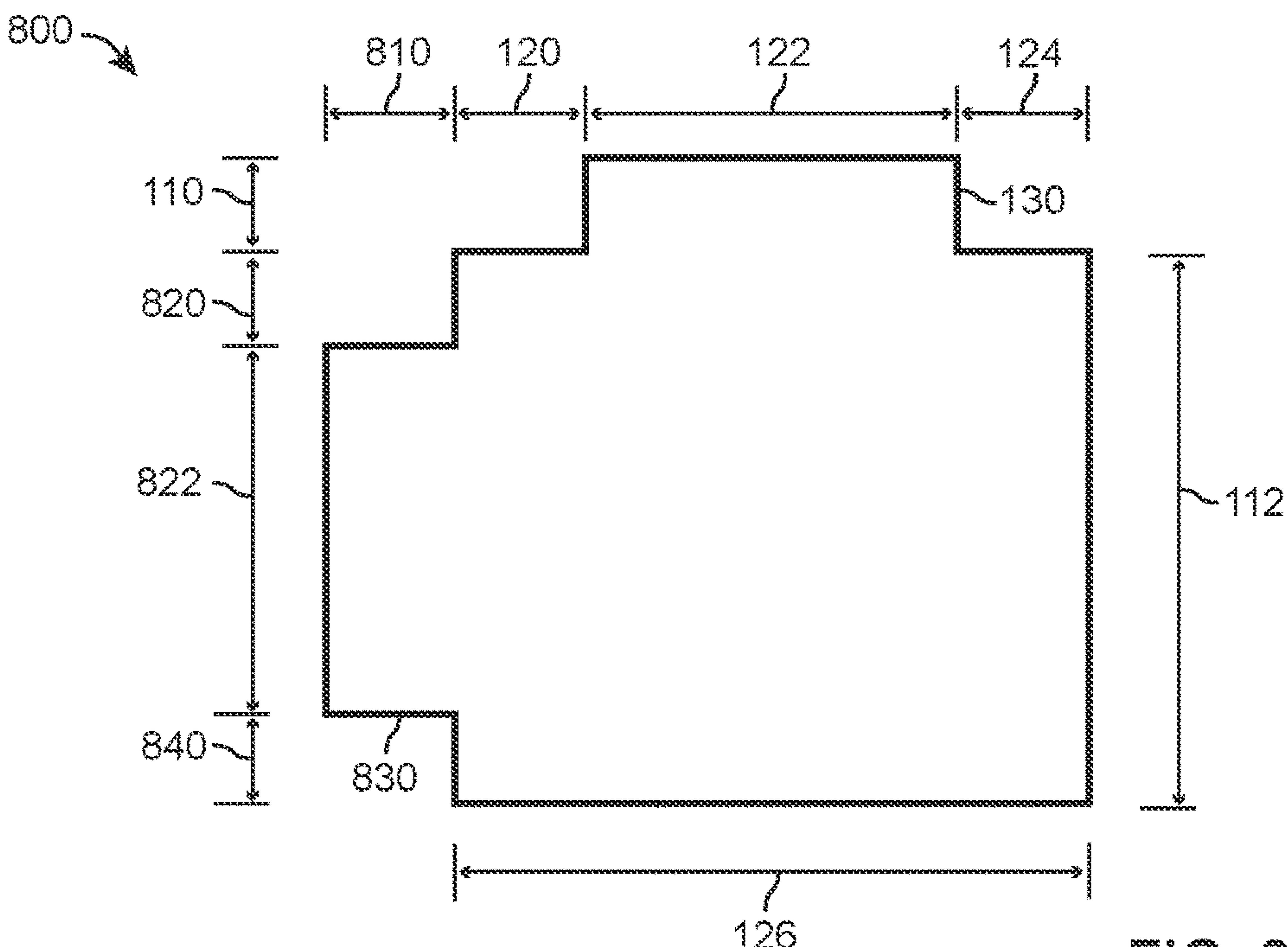

800
810
120
122
124
110
130
820
822
112
840
830
126

FIG. 8

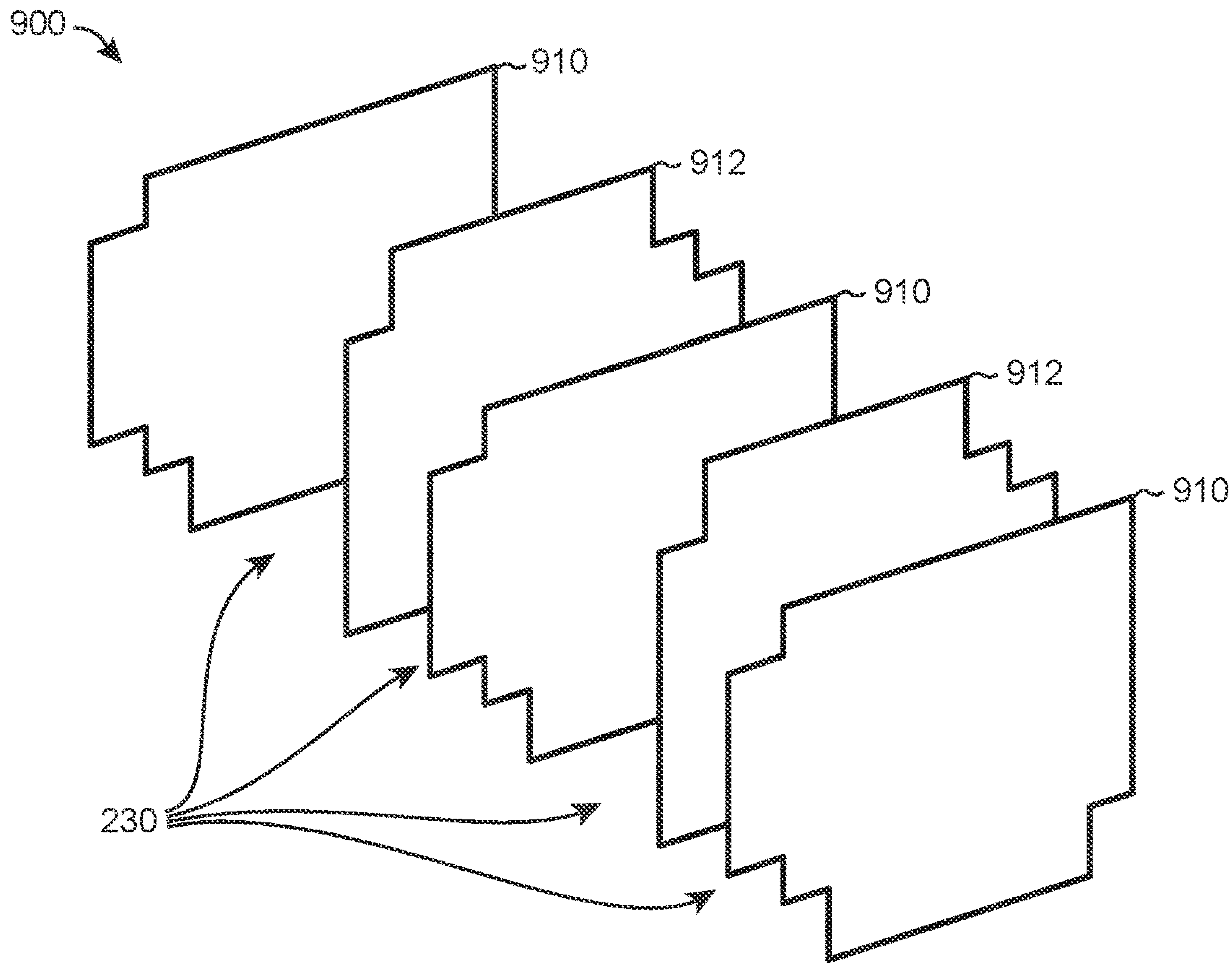


FIG. 9

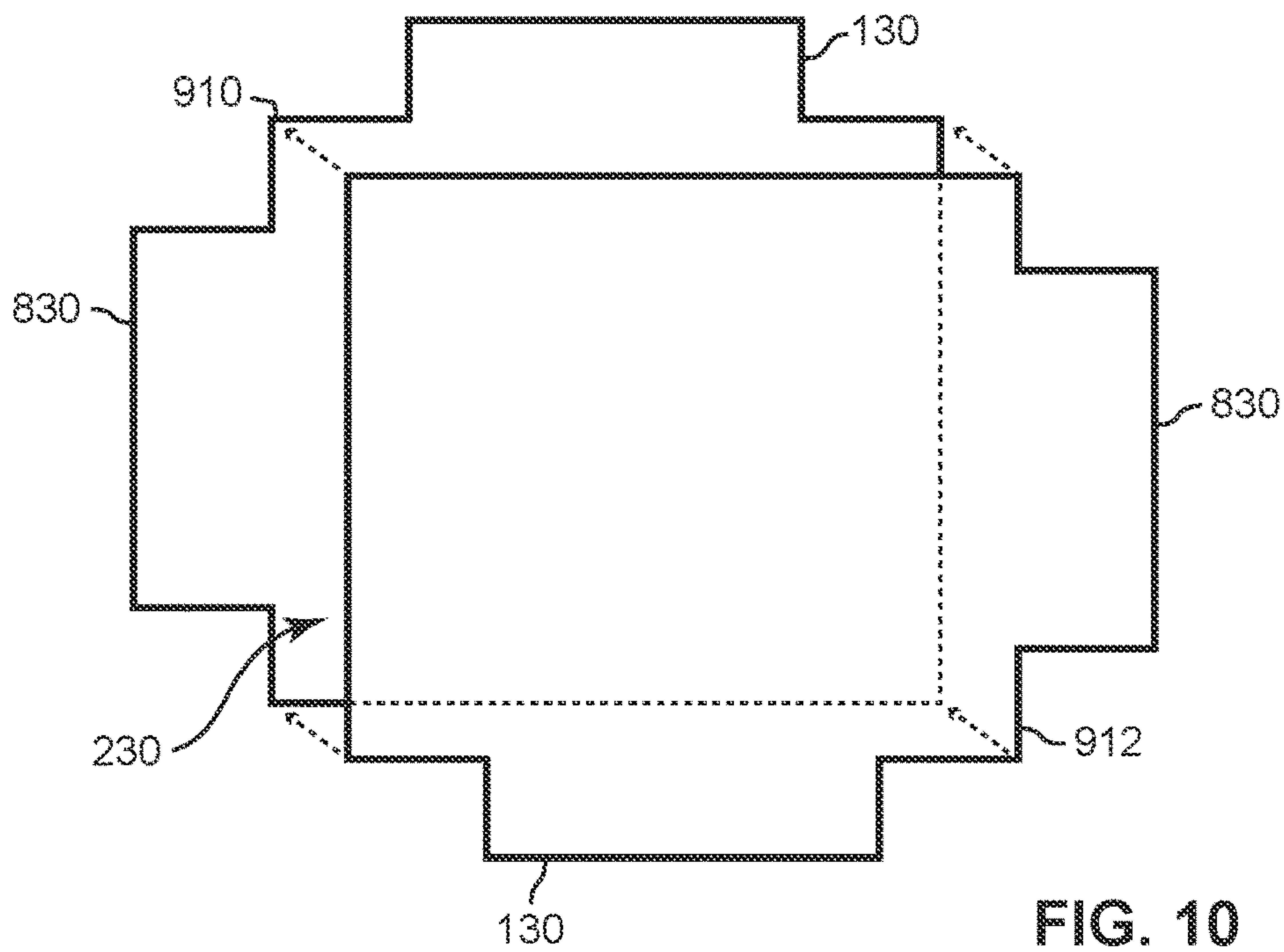
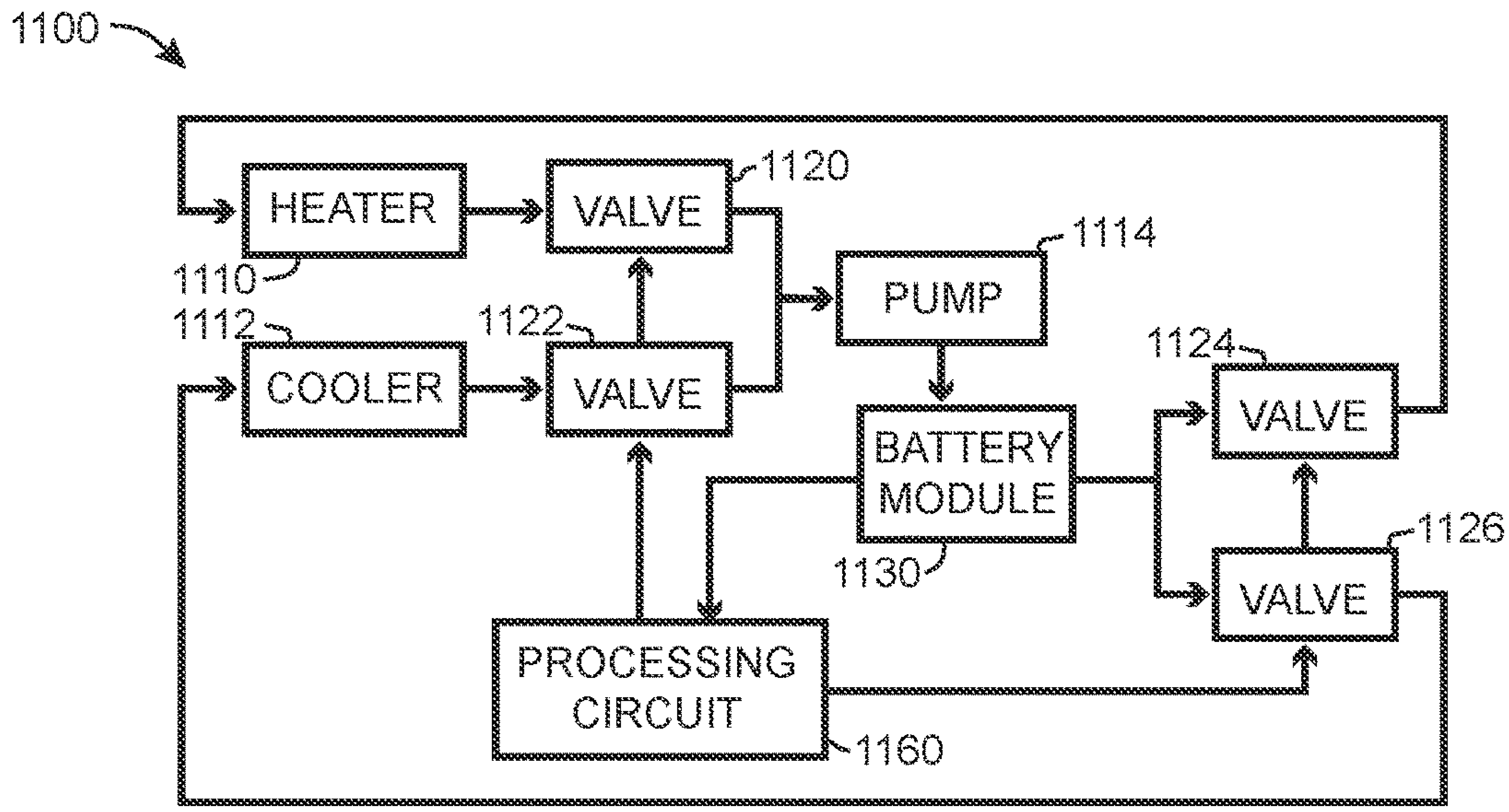


FIG. 10


1100
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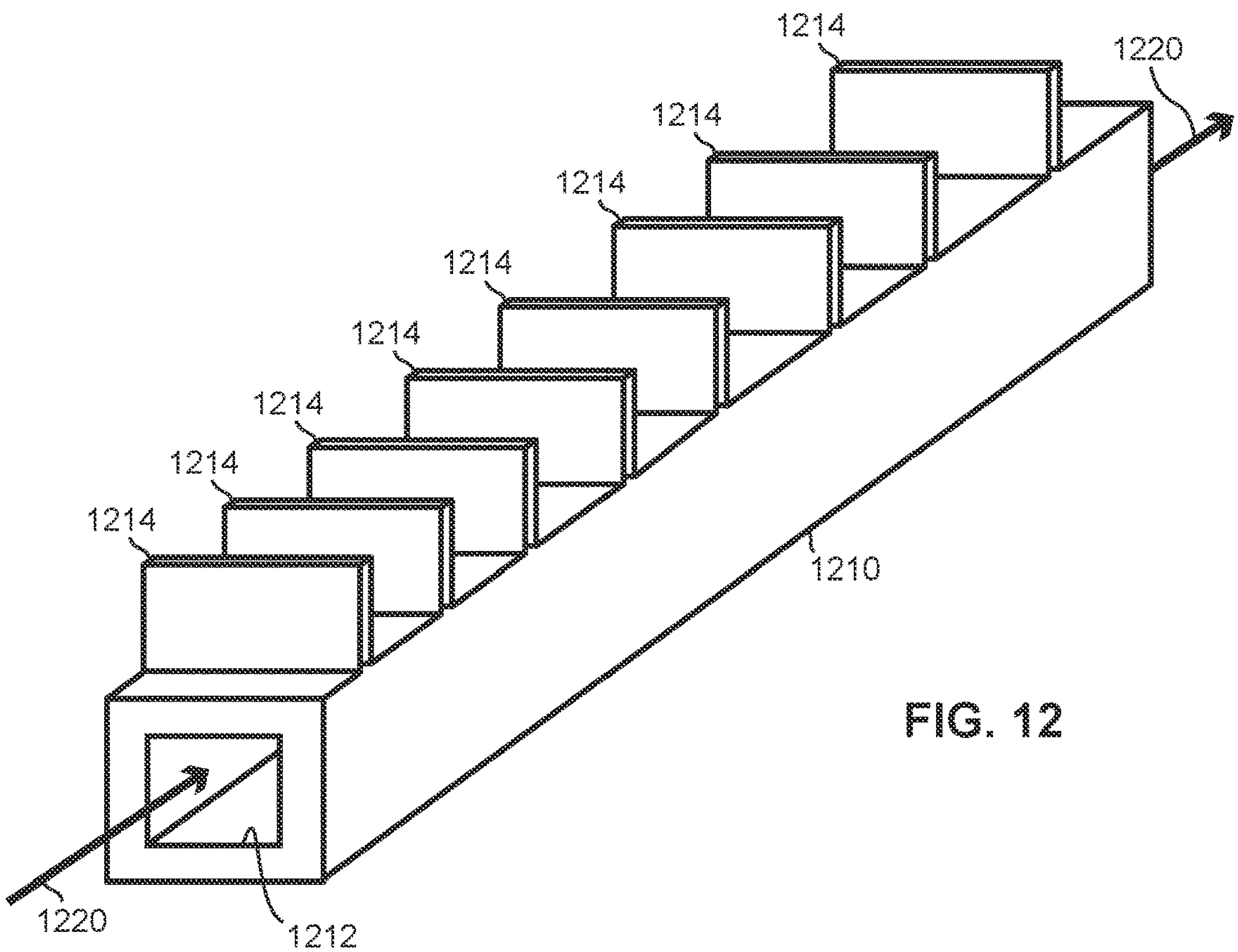
VALVE
1120
1110
PUMP
1114
1112
COOLER
1122
VALVE
1124
VALVE
BATTERY
MODULE
1130
VALVE
1126
PROCESSING
CIRCUIT
1160

FIG. 11


1214
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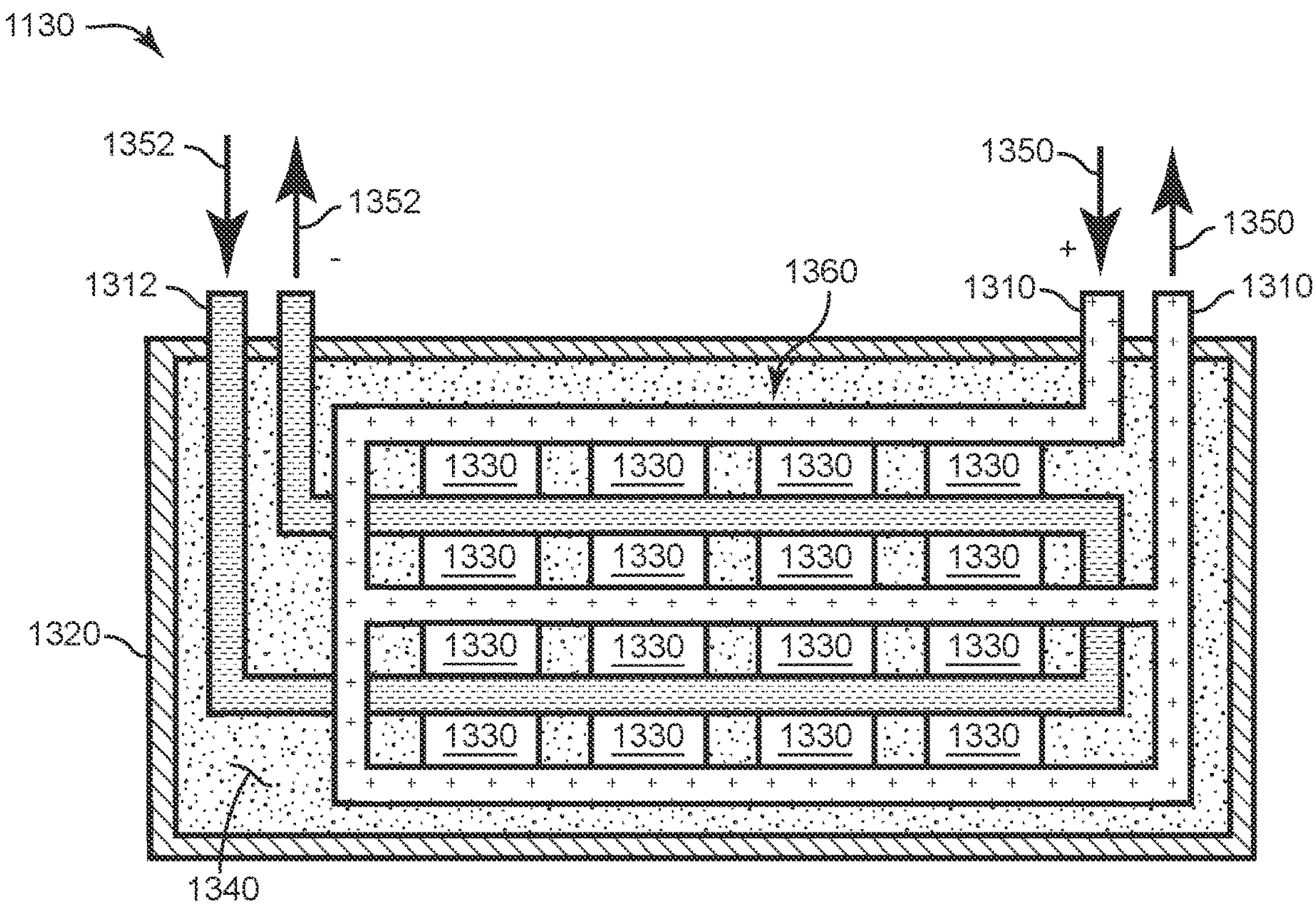
1210
1220
1212

FIG. 12


1130
1352
1352
-
1312
1360
1350
+
1350
1310
1310
1320
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1330
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1340

FIG. 13

METHODS AND APPARATUS FOR A BATTERY AND REGULATING THE TEMPERATURE OF BATTERIES

FIELD OF THE INVENTION

Embodiments of the present invention relate to batteries and regulating the temperature of batteries.

BRIEF DESCRIPTION OF THE DRAWING

Embodiments of the present invention will be described with reference to the drawing, wherein like designations denote like elements, and:

FIG. **1** is a diagram of a collector of a battery according to the present disclosure;

FIG. **2** is a perspective view of a plurality of collectors of FIG. **1** arranged for a battery cell according to the present disclosure;

FIG. **3** is a cross-section of a battery cell along line **3-3** of FIG. **2**;

FIG. **4** is a cross-section of a battery cell along line **4-4** of FIG. **2**;

FIG. **5** is a cross-section of a battery cell along line **4-4** of FIG. **2** with a container and terminals;

FIG. **6** is a diagram of a collector showing the electrical or thermal resistance thereof;

FIG. **7** is the cross-section of the battery cell of FIG. **5** with temperature sensors;

FIG. **8** is a diagram of another implementation of a collector of a battery according to the present disclosure;

FIG. **9** is a perspective view of a plurality of collectors of FIG. **8** arranged for a battery cell according to the present disclosure;

FIG. **10** is a diagram of two collectors of FIG. **8** positioned to establish tabs for an anode and a cathode; and

FIG. **11** is a block diagram of a system for regulating the temperature of a battery module;

FIG. **12** is a perspective diagram of a terminal according to the present disclosure; and

FIG. **13** is a diagram of a battery module according to the present disclosure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following disclosure relates to secondary batteries that may be charged and discharged multiple times. The current provided during discharge of the battery may be used to provide power to an electrical, electro-mechanical, or electronic device. In an application, the current from a battery as disclosed herein may be used to power the electrical, electro-mechanical, and electronic systems of a vehicle.

The battery disclosed herein may include any type of secondary cell that uses any type of chemistry (e.g., chemicals, elements) for storing and providing an electric current. For example, the chemistry of the battery may include aluminum-ion, lead-acid (e.g., deep cycle, VRLA, AGM), lithium-ion (e.g., lithium cobalt oxide, lithium ion), manganese oxide, lithium ion polymer, lithium iron phosphate, lithium-sulfur, lithium-titanate, thin film lithium ion), magnesium-ion, nickel-cadmium, nickel hydrogen, nickel metal hydride, and nickel magnesium cobalt.

The battery disclosed herein includes an anode and a cathode. During discharge of the battery, the anode performs the function of the negative electrode of the battery. During discharge of the battery, the cathode performs the function of the positive electrode of the battery.

The discharge ratings of the battery disclosed herein may be in the range of 2 C to 5 C maximum where a 1 C rating provides one hour of discharge. The charge ratings of the battery may be in the range of 4 C to 5 C.

The battery disclosed herein may be heated or cool. Heat may be extracted from or provided to the battery via a liquid medium (e.g., water, mineral oil, ethylene glycol). The battery may include structures to increase the thermal conductivity of the battery. The battery may include structures to reduce the electrical resistivity of the battery.

The terms cell, battery cell, or battery are used interchangeable to refer to the combination of structure (e.g., collectors, separators, electrodes, case) and chemistry, as discussed above and herein, that cooperate to store and provide a current. A battery may provide a current at a voltage of between 1.5 volts and 9 volts, preferably at a voltage of between 3 volts and 4.5 volts. The voltage range provided by a battery may depend on the chemistry used to store and discharge the current.

Two or more cells, battery cells, and/or batteries may be combined (e.g., electrically coupled, mechanically coupled) to form a battery module. The batteries of a battery module may be electrically coupled in series and/or in parallel.

A battery may include one or more anode collectors, one or more cathode collectors, anode active material, cathode active material, separators, electrolyte, an anode terminal, a cathode terminal, and a case (e.g., housing).

A collector may be formed as a sheet of thin material (e.g., foil). The thickness of the material that forms a collector may be in the range of 0.1 micrometers to 250 micrometers. A collector may be formed of a metal (e.g., aluminum, tin, lead, copper, nickel, gold, zinc, lithium) or combination of metals. A collector may have any suitable shape. A collector may be substantially square, round, or rectangular. A collector may be shaped to increase thermal conductivity and/or reduce electrical resistivity. A collector may be formed of a material with a low electrical resistance and/or a low thermal resistance. A thickness of a collector may be relatively uniform. Portions of a collector (e.g., a tab) may have a thickness that is uniform, but greater than the thickness of the other portions of the collector.

A collector may perform the function of an anode collector or a cathode collector. A collector may be combined with anode active material to form an anode collector. Any material may be used as anode active material or cathode active material that is suitable with the chemistry of the battery and/or the material that forms the collector. Anode active material and/or cathode active material may include a binder that holds the active material together and/or binds the active material to the collector. Active material may be positioned on one side or both sides of a collector.

Anode active material may include any material suitable for the chemistry of the battery, the material of the anode collector and/or the material of the cathode collector. For example, the anode active material for a battery that uses a form of lithium chemistry may include graphite and copper (e.g., graphite coated on copper foil).

Cathode active material may include any material suitable for the chemistry of the battery, the material of the anode collector and/or the material of the cathode collector. For example, the cathode active material for a battery that uses a form of lithium chemistry may include lithium nickel cobalt manganese oxide, lithium manganese oxide, or lithium cobalt oxide.

A separator separates an anode collector from one or more cathode collectors. A separator may separate (e.g., keep separate) anode active material and cathode active material. A separator may function as a catalyst that promotes the movement of ions between an anode and a cathode. A separator may be porous. The pores of a separator may be evenly spaced. Ions may pass through the pores of the separator. A separator may be formed of a material that is non-conductive (e.g., not electrically conductive). For example, a separator may be formed a ceramic material. Other materials suitable for a separator include polyolefin films, nylon, and cellophane. A separator may be surrounded by, immersed in, and/or in contact with an electrolyte.

An electrolyte includes any material suitable for a chemistry that facilitates the transport of ions between an anode and a cathode. An electrolyte may include soluble salts, acids or other bases. An electrolyte may produce ions through a chemical reaction. The consistency (e.g., viscosity) of an electrolyte may range from a powder to paste to a liquid. For example, an electrolyte for a form of lithium chemistry may include lithium salts with ethylene carbonate.

A terminal is formed of an electrically conductive material (e.g., low electrical resistance). For example, a terminal may be formed of a metal (e.g., aluminum). A terminal electrically couples to one or more collectors of a battery. A terminal may be positioned, at least partially, on an exterior of the case of the battery to enable electrical and mechanical coupling to the battery. A terminal may be formed of a material that facilitates the flow of current through the terminal. A terminal may be formed of a material that facilitates the flow of current to and from the one or more collectors coupled to the terminal. A terminal may facilitate the flow of current by presenting a low resistance to a current.

One terminal may couple to anode collectors while another terminal may couple to cathode collectors. A terminal that couples to anode collectors may be referred to as an anode terminal or the negative terminal of a battery. A terminal that couples to cathode collectors may be referred to as a cathode terminal or the positive terminal of a battery. An anode terminal is kept electrically separate from a cathode terminal. An anode terminal and a cathode terminal cooperate to provide a current to a load. An anode terminal and a cathode terminal cooperate to receive a current to recharge a battery.

A terminal may also be formed of a material that is thermally conductive (e.g., low thermal resistance). For example, a terminal may be formed of a metal (e.g., aluminum). A terminal may facilitate the transfer of heat. A terminal may facilitate a transfer of heat to or from a collector. A terminal may facilitate a transfer of heat to and from a battery and/or a battery module. A terminal may include structures (e.g., fins, radiators, plates) for increasing a surface area of the terminal to increase a transfer of heat to and/or from the terminal. A terminal may include a duct (e.g., cavity, channel). A medium (e.g., air, liquid) may flow through the duct to facilitate the transfer of heat to and from the collectors via the terminals.

A terminal may be coupled to one or more collectors in such a manner so as to not increase an electrical and/or thermal resistance of the terminal or the collector, at least not significantly. A collector may have an electrical resistance. A terminal may have an electrical resistance. Coupling the terminal to the collector couples the electrical resistance of the terminal in series with the electrical resistance of the collector. If the coupling (e.g., area of contact, connection) between the terminal and the collector includes an electrical resistance, then the electrical resistance of the collector and terminal is increased by the electrical resistance of the coupling. If the electrical resistance of the coupling is greater than the resistance of the collector and/or the resistance of the terminal, then the resistance of the collector coupled terminal may increase significantly.

A coupling formed of a low resistance material (e.g., metal) may reduce the resistance of the coupling and thereby avoiding a substantial increase the resistance of the collector and terminal. For example, welding a metal collector to a metal terminal might provide a coupling with a low resistance.

A case may enclose (e.g., house, contain, surround) a battery. A case may enclose all or substantially all of the material of the one or more collectors of the battery, the anode active material, the cathode active material, the separator, and the electrolyte. A case may enclose at least a portion of the two or more terminals of a battery. A case may perform the function of one terminal of a battery. A case may be formed of a material that is suitable for containing the above. A case may be formed of a rigid material (e.g., metal, plastic). A case may be formed of a flexible material (e.g., plastic, mylar, polymer). A case may contain a liquid electrolyte. A case may include one or more vents or venting an excess buildup of pressure inside the battery. A case may be formed of a material that is thermally conductive. In an implementation, case **550** is formed of a metal.

In an implementation, battery **300** of FIGS. **1-7**, includes cathode collectors **210**, anode collectors **212**, chemistry **230**, case **550**, anode terminal **512** and cathode terminal **510**. Chemistry **230** includes anode active material **312**, separator **314**, cathode active material **310**, and electrolyte **316**.

Chemistry **230** may also be referred to as a unit of chemicals. A unit of chemicals may be positioned between to collectors. The unit of chemicals interacts with the collectors so that one collector performs the functions of an anode collector while the other collector performs the functions of a cathode collector. As discussed below, a unit of chemicals may include anode active material, cathode active material, a separator, and an electrolyte.

Cathode collector **210**, anode collector **212**, chemistry **230**, and case **550** include the structure and materials and perform the functions of a cathode collector, anode collector, chemistry, and case respectively as discussed above. Anode terminal **512** and cathode terminal **510** include the structure and materials and perform the functions of a terminal discussed above.

Chemistry **230** includes anode active material **312**, separator **314**, cathode active material **310**, and electrolyte **316**. Chemistry **230** is positioned between an anode collector and a cathode collector. Tab **130** of each anode collector **212** couples to anode terminal **512**. Tab **130** of each cathode collector **210** couples to cathode terminal **510**. Tabs **130** of each collector couples to its respective terminal along the entire width (e.g., **122**) of tab **130** to provide parallel paths for current flow to and from the collector. Parallel paths through tab **130** present a low electrical and/or thermal resistance to currents and heat that enter and leave the collector.

In this implementation, the cathode collectors **210** and anode collectors **212** are formed of aluminum or copper. Each cathode terminal **510** and anode terminal **512** is formed of aluminum or copper. Each cathode collector **210** and anode collector **212** is welded to its respective terminal **510** or **512**.

Cathode collectors **210** and anode collectors **212** are formed in accordance with collector **100**. Collector **100** is formed of a thin sheet (e.g., foil) of material. In an implementation, collector **100** is formed of aluminum or copper. The characteristics of collector **100** may include the characteristics of a collector discussed above. Collector **100** has width **126** and height **112**. Width **126** and height **112** of collector **100** form an area of any size that is suitable for the chemistry used in battery **300**. The area bounded by width **126** and height **112** may be referred to as the active area of a collector or simply the area of a collector. The active area interacts with the chemicals of the battery chemistry to perform the functions of a battery.

In an implementation, width **126** is equal to height **112**. If an upward direction is considered 0 degrees and a downward direction 180 degrees, the area of adjacent collectors may be aligned with the tab of adjacent collectors oriented in a direction of 0, 90, 180 and 270 degrees. In implementation show in FIG. **2**, the tabs of collectors are alternately oriented at 0 and 180 degrees. The tabs of collectors may also be alternately oriented at 0 and 90, 0 and 270, 90 and 270 without overlapping the tabs of adjacent (e.g., anode and cathode) collectors.

In another implementation, width **126** is in the range of 40-50 millimeters, preferably about 45 millimeters. Height **112** is in the range of 50 to 60 millimeters, preferably 55 millimeters. The area of collectors of these dimensions may be aligned by orienting the tab of one collector at 0 degrees and the tab of another collector at 180 degrees.

Collector **100** includes tab **130**. Tab **130** extends from the area. Tab **130** extends from the area in a direction. Tab **130** has height **110** and width **122**. Width **122** of tab **130** is at least 70 percent of width **126**. Preferably, width **122** is at least 80 percent of width **126**. The width of tab **130** reduces electrical and/or thermal resistance between the terminal to which the tab is coupled and the area of the collector. Preferably, width **120** and **124** are equal so that tab **130** is centered with respect to width **126**.

Height **110** of tab **130** is sufficient to permit tab **130** to couple to either cathode terminal **510** or **512**. In an implementation, height **110** is at least 12 millimeters which means tab **130** extends at least 12 millimeters from the area of the electrode.

The electrical and thermal resistance of collector **100** and cathode terminal **510** are shown in FIG. **6**. The material of collector **100** is a thin sheet. The resistors R shown in FIG. **6** illustrate the resistance of the material at any point in tab **130**, the area of collector **100**, and cathode terminal **510**. The resistors of the area of collector **100**, tab **130**, and cathode terminal **510** are perceived by a current as being in parallel. Because there are many resistors are in parallel, the area of collector **100**, tab **130** and cathode terminal **510** present a low electrical and thermal resistance to a current that flows along the entire width of tab **130**. Currents that flow in to or out of the area of a collector flow along an entire width of tab **130**.

Another way to assess the resistance of tab **130** with respect to its width to determine the squares of material through which the current or heat must flow. A square of sheet material has a resistance. Because the path of current flow through tab **130** is many squares wide (e.g., about 5; width **122** divided by height **110**) and only one square long (e.g., height **110**), the resistance through tab **130** is proportional to width **122**/height **110**. (e.g., Rtab130=Rsheet*(width **122**/height **110**)). As the width of tab **130** decreases, the resistance, both electrical and thermal, increases. The width (e.g., **122**) of tab **130** with respect to the width (e.g., **126**) and height (e.g., **112**) of the area of the collector is very beneficial to the operation of the battery because the wide width provides a low resistance path between the terminal and the area of the collector. The low resistance path increases the density of the current that may be provided to or received from the collector and the rate at which heat may be provided to or removed from the collector.

The thickness of the material of tab **130** also affects the resistance of tab **130**. As the thickness of the material increases, the resistance to electricity and heat transfer decreases.

Two or more collectors **100** are positioned with respect to each other to form cathode collectors **210** and anode collectors **212** of a battery. In placement **200**, cathode collectors **210** and anode collectors **212** are alternately positioned with respect to each other. In placement **200**, cathode collectors are positioned so that tab **130** of each cathode collector **210** is positioned downward, while anode collectors **212** are positioned so that tab **130** of each anode collector **212** is positioned upward. Using the degree notation for orientation discussed above, the tabs of the anode collectors **212** are oriented in the direction of 0 degrees while the tabs of the cathode collectors **210** are oriented in the direction of 180 degrees. The difference in the direction of orientation of the tabs of the anode collectors **212** with respect to the tabs of the cathode collectors **210** is 180 degrees. Tabs **130** of the anode collectors **212** do not overlap the tabs of cathode collectors **210**. Further, Tabs **130** of anode collectors **212** do not overlap that area (e.g., height **112** by width **126**) of the cathode collectors **210** and tabs **130** of cathode collectors **210** do not overlap the area of anode collectors **212**.

Placement **200** shows how two or more sheet-like collectors are stacks to form a battery. Chemistry (e.g., a unit of chemicals) is placed between collectors. The chemical make-up (e.g., active material) of the chemistry between collectors causes a collector to operate as an anode collector or a cathode collector.

In an implementation, the area (e.g., height **112** by width **126**) of a cathode collector **210** aligns with the area of an anode collector so that tab **130** of the cathode collectors **210** extend from the bottom of placement **200** while tab **130** of anode collectors **212** extend from the top of placement **200**. As a result of placement **200**, cathode collectors **210** extend from the bottom of the battery **300** while anode collectors **212** extend from the top of the battery **300**.

In another implementation, the tabs of the anode collectors **212** are oriented at 0 degrees while the tabs of the cathode collectors are oriented at 90 or 270 degrees. The difference in the direction of orientation of the tabs of the anode collectors **212** with respect to the tabs of the cathode collectors **210** is 90 degrees. The tabs of the anode collectors **212** do not overlap the tabs of the cathode collectors **210**. The tabs of the anode collectors **212** do not overlap that area of the cathode collectors **210** and the tabs of the cathode collectors **210** do not overlap the area of the anode collectors **212**.

Chemistry **230** is positioned between cathode collectors **210** and anode collectors **212** as shown in FIGS. **2-5** and **7**. Chemistry **230** includes any of the chemistries (e.g., chemicals, compounds, elements) discussed above. Chemistry **230** includes any chemistry suitable for the material of cathode collectors **210** and anode collectors **212**. Chemistry **230** may come into contact with cathode collector **210** and/or anode collector **212**. Chemistry **230** may adhere (e.g., stick) to cathode collector **210** and/or anode collector **212**. Chemistry **230** does not contact tab **130** of cathode collectors **210** or anode collectors **212**. Chemistry **230** interacts with cathode collectors **210** and anode collectors **212** to perform the functions of the battery, such as storing and providing a current.

Battery **300** may include any number of cathode collectors **210** and anode collectors **212** for a type of battery, a chemistry used, a voltage delivered, and/or a current delivered and/or received.

The cross-section along line **3-3** shown in FIG. **3** illustrates how the tabs of anode collectors **212** extend above battery **300** and the tabs of cathode collectors **210** extend below battery **300**. The extension of tabs **130** above and below battery **300** provide parallel paths to each collector to provide a current to recharge battery **300**, receive a current to discharge battery **300**, provide heat to heat battery **300** and remove heat to cool battery **300**. The parallel paths reduce electrical and thermal resistance of the collector and battery **300**.

The width of tab **130** of each collector provides a low resistance path for current flow (e.g., charging, discharging) or heat transfer (e.g., provide heat, remove heat). Tab **130** should be coupled to cathode terminal **510** or anode terminal **512** along an entire width of tab **130** to preserve the wide, low resistance path for current flow and heat transfer. The structure (e.g., coupler) that couples tabs **130** to cathode terminals **510** and anode terminals **512** respectively should also be of a low electrical and thermal resistance so as to not introduce a high resistance in the wide path that tab **130** provides between the terminal and the area of the collector. For a collector and terminal formed of metal, welding tab **130** to the terminal across the entire width of tab **130** provides a low resistance coupling of tab **30** to the terminal. The weld joint represents a low resistance coupler.

The thickness of tab **130**, not width **122** but the thickness of the material of tab **130**, may be thicker than the thickness of the area of collector **100** to reduce the electrical and/or thermal resistance between a terminal and the area of collector **100**. Tab **130** may include ribs, not shown, of thicker material positioned across tab **130** between the end of tab **130** and the area of collector **100**. The ribs provide additional low resistance, parallel paths between a terminal and the area of collector **100**. A rib may extend from tab **130** into the area of collector **100** to decrease the resistance of a portion of the area and/or to provide parallel paths for current and heat flow.

In an implementation, the electrical resistance between any location on area of a collector to cathode terminal **510** or anode terminal **512**, refer to FIG. **5**, is between 1 and 10 milliohms. The resistance to heat transfer between any location on the area if the cathode to cathode terminal **510** or anode terminal **512** is similarly low. Width **122** of tab **130** provides a wide, low resistance path, both electrically and thermally, between cathode terminal **510** and the area of the collector. A low resistance coupler between tab **130** and cathode terminal **510** increases the resistance of cathode terminal **510** to any location on the area of the collector, but only by a small amount. Further, because the coupler is along the entire length of tab **130**, the coupler also provides may parallel paths for current flow and heat transfer. In an implementation, each cathode collector **210** and each anode collector **212** is formed of aluminum and is welded to its respective cathode terminal **510** and anode terminal **512**, which are also formed of aluminum. Welding provides a low electrical and thermal resistance between tab **130** and the terminal.

Anode active material **312** is positioned next to or couples to one or both sides an anode collector **212**. Anode active material **312** performs the functions of an anode active material discussed above. Cathode active material **310** is positioned next to or couples to one or both sides a cathode collector **210**. Cathode active material **310** performs the functions of a cathode active material discussed above.

Separator **314** is positioned between anode active material **312** and cathode active material **310**. Separator **314** separates anode active material **312** from cathode active material **310**. Separator **314** is formed of a porous material (e.g., ceramic). Separator **314** permits the passage of ions between anode collector **212** and cathode collector **210**. Separator **314** snakes through, refer to FIG. **4**, battery **300**. Separator **314** provides some rigidity to the structure of battery **300**.

Electrolyte **316** is position in and around separator **314**, anode active material **312**, and cathode active material **310**. Electrolyte **316** performs the functions of an electrolyte as discussed above.

Case **550** encloses anode active material **312**, separator **314**, cathode active material **310**, electrolyte **316**, and the area (e.g., width **126** by height **112**) of anode collectors **212** and cathode collectors **210**. Tab **130** of anode collectors **212** and cathode collectors **210** extend through case **550**. Case **550** may include the materials and perform the functions of a case as discussed above. Anode terminal **512** couples to tab **130** of each anode collector **212**. Cathode terminal **510** couples to tab **130** of each cathode collector **210**. Cathode terminal **510** and/or anode terminal **512** may be position wholly or partially outside of case **550**. Cathode terminal **510** and/or anode terminal **512** may couple to case **550**. Cathode terminal **510** and anode terminal **512** are kept electrically separate from each other. Separating cathode terminal **510** and anode terminal **512** reduces the likelihood of shorting out battery **300**.

Cathode terminals **510** and anode terminals **512** may be used to provide electrical current to cathode collectors **210** and anode collectors **212** respectively. Cathode terminals **510** and anode terminals **512** may further provide heat to or remove heat from battery **300** via cathode collectors **210** and anode collectors **212**.

In an implementation of cathode terminal **510** and/or anode terminal **512**, refer to terminal **1210** of FIG. **12**, terminal **1210** includes one or more structures to increase the surface area of terminal **1210** to facilitate transfer of heat to or from battery **300**. In an implementation, terminal **1210** includes fins **1214**. Each fin mechanically and thermally couples to terminal **1210**. Each fin **1214** increases the surface area of terminal **1210**. Each fin **1214** decreases the thermal resistivity (e.g., increases thermal conductivity) between a medium (e.g., air, liquid) that surrounds terminal **1210** and the collectors (e.g., **210**, **212**) of battery **300**. Terminal **1210** may include fins on all or just some sides of terminal **1210**.

A terminal may include any type of structure for increasing the surface area of the terminal to facilitate heat transfer. For example, terminal **1210** may include fins that extend straight out from one or more sides of terminal **1210** as shown in FIG. **12**. The space between fins is a factor in the efficiency of the energy transfer of the terminal. Fin spacing may be expressed as fins per inch ("FPI").

The spacing may be decreased (e.g., increased FPI) to increase the surface area of terminal **1230**. Having the fins close to each other decreases the amount of medium (e.g., liquid) positioned between fins at any time. Closely spaced fins (e.g., 20-30 FPI) may restrict the flow of medium between the fins so that the temperature of the medium while between the fins changes more than a threshold. For example, the FPI may restrict medium flow so that the medium approaches its boiling point or freezing point while between fins thereby decreases the efficiency of heat transfer. Fin spacing and rate of flow of the medium to maintain efficient heat transfer are inversely proportional.

The space between fins may be increased (e.g., 5-18 FPI) so that the temperature change of the medium between fins is less than when the fins are closer together. An increased spacing between fins permits more medium to pass between fins so that the heat transferred to or from the medium has a lesser effect on the temperature of the medium between fins. Preferably, the change in the temperature of the medium between fins is less than a threshold. For example, the amount of medium between fins limits the change in the temperature of the medium between the fin so that it increases to within a threshold of its boiling point or decreases to with in a threshold of its freezing point. The threshold of temperature change may also be express as no more than a threshold difference between the temperature of the medium that is positioned between fins as compared to the temperature of the medium that is not positioned between fins.

Fins may be flared with respect to each other so that the distance between adjacent fins proximate to the terminal is less than the distance between the fins at a distance away from the terminal. Flaring increase the amount of medium that can pass between fins.

Fins may be shaped to increase the amount of time a medium moves between fins for a particular rate of flow. For example, fins may be V-shaped to increase a linear length along adjacent fins.

The surface area of a terminal may be increase by forming or attaching pins (e.g., cylindrical, rectangular) to the terminal. A cylindrical pin has a diameter and a height. A cylindrical pin extends a height from the terminal. A rectangular pin has a width and a depth that is about the same and extends a height from the terminal. Pins may be spaced to transfer heat to a medium as discussed above with respect to fins. Pins may be flared with respect to each other.

The thickness of fins or pins may be decreased or increased to increase or decrease respectively the transfer of heat via the fins or pins.

Fins or pins may be formed of a material that is different from the material of the terminal to increase or decrease the efficiency of heat transfer via the fins.

In another implementation of terminal **1210**, terminal **1210** includes channel **1212**. A medium (e.g., fluid, liquid) flows through channel **1212** along flow path **1220**. The medium facilitates the transfer of heat to or removal of heat from battery **300** via anode collector **212** and cathode collector **210** of battery **300**.

In another implementation of terminal **1210**, terminal **1210** includes both fins **1214** (or pins) and channel **1212**.

Another implementation of battery **300** includes collectors that have the shape and characteristics of collector **800**, shown in FIGS. **8-10**. The characteristics of collector **800** may include the characteristics of a collector discussed above. Collector **800** is formed of a thin sheet of material. Collector **800** includes an area defined by width **126** and height **112** as discussed above. Preferably, width **126** is equal to height **112** to facilitate aligning the active areas of cathode and anode collectors. Collector **800** includes tab **130**, as discussed above, and tab **830**. Tab **830** may include all of the characteristics and perform the functions of a tab as discussed above. Tab **830** may be substantially the same as tab **130**, except for orientation and possibly width depending on the width **126** and height **112** of collector **800**.

Tab **130** extends from the area of collector **800** in a first direction. Tab **830** extends from the area of collector **800** in a second direction. In the implementation shown in FIG. **8**, tab **130** extends from the area in a direction of 0 degrees, while tab **830** extends from in a direction of 270 degrees. The difference in the directions of orientation of tab **130** and tab **830** is 90 degrees.

The width of tab **830** is width **822**. The height of tab **830** is height **810**. Width **822** is at least 70 percent of height **112**. Preferably, width **822** is at least 80 percent of height **112**. Preferably, width **820** and **840** are equal so that tab **830** is centered with respect to height **112**. Height **810** of tab **830** is sufficient to permit tab **830** to couple to a terminal. As discussed above with respect to tab **130**, the width of tab **830** reduces electrical and/or thermal resistance between the terminal to which the tab is coupled and the area of the collector.

Two or more collectors **800** are positioned with respect to each other to form cathode collectors **910** and anode collectors **912** of a battery. In placement **900**, cathode collectors **910** and anode collectors **912** are alternately positioned with respect to each other. In placement **900**, cathode collectors are positioned so that tab **130** and tab **830** of each cathode collector **910** are oriented downward (e.g., 180 degrees) and to the left (e.g., 270 degrees) respectively, while anode collectors are oriented so that tab **130** and tab **830** of each anode collector **212** are positioned upward (e.g., 0 degrees) and to the right (e.g., 90 degrees) respectively. The area (e.g., height **112** by width **126**) of cathode collector **910** aligns with area of anode collector **912** so that tab **130** and tab **830** of cathode collectors **210** extend from the bottom and left respectively of placement **900** while tab **130** and tab **830** of anode collectors **212** extend from the top and right respectively of placement **900**. Tabs **130** and **830** of anode collectors **912** do not overlap tabs **130** and **830** of cathode collectors **910**. Further, tabs **130** and **830** of the anode collectors **912** do not overlap that area of the cathode collectors **910** and tabs **130** and **830** of cathode collectors **910** do not overlap the area of the anode collectors **212**.

In another implementation, the tab **130** of collector **800** is oriented at 0 degrees and tab **830** is oriented at 180 degrees. For this implementation, the placement of cathode collectors **910** with respect to anode collectors **912** orients tab **130** and tab **830** of cathode collectors at 0 degrees and 180 degrees respectively while tab **130** and tab **830** of anode collectors are oriented at 90 and 270 degrees respectively. Tabs **130** and **830** of anode collectors **912** do not overlap tabs **130** and **830** of cathode collectors **910**. Tabs **130** and **830** of anode collectors **912** do not overlap that area of cathode collectors **910** and tabs **130** and **830** of cathode collectors **910** do not overlap the area of anode collectors **912**.

Chemistry **230** is positioned in between cathode collectors **910** and anode collectors **912** in the area defined by height **112** and width **126**. Chemistry **230** includes any of the chemistries (e.g., chemicals, compounds, elements) discussed above. Chemistry **230** includes any chemistry suitable for the material of cathode collectors **910** and anode collectors **912**. Chemistry **230** may come into contact with cathode collector **910** and/or anode collector **912**. Chemistry **230** may adhere (e.g., stick) to cathode collector **910** and/or anode collector **912**. Chemistry **230** does not contact tab **130** or tab **830** of cathode collectors **910** or anode collectors **212**. Chemistry **230** interacts with cathode collectors **910** and anode collectors **912** to perform the functions of the battery, such as storing and providing a current.

Anode terminal **512** couples to tab **130** and tab **830** of each anode collector **912**. Cathode terminal **510** couples to tab **130** and tab **830** of each cathode collector **910**. As discussed above with respect to tab **130**, tab **130** and tab **830** of each collector couples to its respective terminal along the entire width (e.g., **122**) of tab **130** and along the entire width (e.g., **822**) of tab **830** to provide parallel paths along tab **130** and tab **830** for current flow to and from the collector and heat transfer to and from the collector. The wide, parallel paths through tab **130** and tab **830** present a low electrical and/or thermal resistance to currents and heat that enter and leave the collector.

In addition to the width of tabs **130** and **830**, having two tabs (e.g., **130**, **830**) per collector provide two parallel paths to the area (e.g., height **112** by width **126**) of the collector thereby further reducing electrical and thermal resistance within battery **300**. Two tabs per collector increases the surface area of the terminals coupled to a collector thereby improving heat transfer to and from battery **300**. Two tabs per collector decreases the electrical resistance between the terminals and the area of the collector thereby providing greater current density of currents to and from battery **300**. Two tabs per collector improves both the electrical and thermal characteristics of battery **300**.

Tabs **130** and **830** of each collector couple to a terminal as discussed above. Tabs **130** and **830** of each collector couple to its terminal along the entire width (e.g., **122**, **822**) of tab **130** and tab **830** to provide a low resistance path between the terminal and the area of the collector. Current and heat may be transferred to and from each collector as discussed above.

A battery may include temperature sensors. Temperature sensors may sense the temperature of a terminal, the chemistry, a case, and/or a collector of a battery.

A battery may include temperature sensors. A temperature sensor may be positioned inside a battery. A temperature sensor may be positioned in a case of the battery. A temperature sensor may be positioned on or in a terminal of a battery. A temperature sensor may be positioned in a chemistry of the battery. A temperature sensor may report a magnitude of the temperature that it detects. A temperature sensor may report a temperature of a collector, the chemistry, a case, and/or a terminal of a battery. A temperature sensor may report its position (e.g., location). A temperature sensor may sensor may report its position relative to the structure of the battery (e.g., which collector, which terminal, which part of chemistry, which part of the case). A temperature sensor may report its position relative to the structure of a battery module (e.g., which battery in the module). A temperature sensor may report its position relative to the structure of a battery and the structure of a battery module.

For example, battery **700** includes temperature sensors **710**, **712**, **714**, **716**, **718** and **720**. A battery may include one or more of temperature sensors **710**, **712**, **714**, **716**, **718** and **720**. Temperature sensor **710** and **720** detect and report the temperature of cathode terminals **510** and anode terminals **512** respectively. Temperature sensor **714** and **716** detect and report the temperature of one or more collectors, case **550**, and/or the chemistry in a portion of the battery proximate to anode terminal **512** and cathode terminal **510** respectively. Temperature sensor **718** detects and reports the temperature of one or more collectors and/or the chemistry in a center portion of the battery. Temperature sensor **720** detects the temperature of a collector and/or the case on a side of the battery.

A temperature sensor may report a detected temperature as analog and/or digital information. A temperature sensor may report information to a processing circuit. A temperature sensor may include a bus for providing analog and/or digital information to a processing circuit. A bus may include two or more conductors for carrying an electrical signal from a temperature sensor to a processing circuit.

The components of a battery may include an identifier (e.g., number, letter, alphanumeric) to identify the portion of the battery where the temperature sensor is placed. The identifiers for each components of a battery may be different. For example, anode terminal **512** may have one identifier (e.g., TN**01**) and cathode terminal **510** may have another identifier (e.g., TP**01**). If a battery has more than one terminal, each terminal may have a different identifier. Each collector may include an identifier. For example, anode collectors **212** may be identified from left to right in FIG. **7** as AC**01**, AC**02**, AC**03**, and AC**04**. Cathode collectors **210** may be identified from left to right as CC**01**, CC**02** and so forth. The internal volume of a battery may be divided into smaller volumes and assigned identifiers. The position of collectors may be used to subdivide the volume of a battery. A case may be divided into portions with associated identifiers.

A temperature sensor may include an identifier. Information regarding the location of a temperature sensor with respect to a battery may be programed into a temperature sensor. For example, temperature sensor **716** may be programmed with an identifier indicating its proximity to anode collector AC**03**, cathode connector CC**02** and/or the location proximate to cathode terminal **510**. Temperature sensor **718** may be programed with an identifier indicating its proximity to anode collector AC**03**, cathode connector CC**03**, and the central portion of the battery. Temperature sensor **720** may be programed with an identifier indicating its position in the center of the left side of case **550**. Each time a temperature sensor reports the temperature it detects, the temperature sensor reports the detected temperature, its own identifier and the programmed identifier for the location of the temperature sensor in the battery.

In another implementation, a temperature sensor may include an identifier. A processing circuit stores information as to the location of each temperature sensor in a battery or each temperature sensor in a battery module. The location information stored by the processing circuit may be stored relative to the identifier for each temperature sensor in the battery and/or the module. Each time a temperature sensor reports the temperature it detects, the temperature sensor reports the detected temperature and its own identifier. The processing circuit uses the identifier of the temperature sensor to lookup the location of the sensor in the battery and/or the battery module.

A processing circuit may use the combination of detected temperature and the location of the detected temperature to detect portions of a battery or a battery module that are not within a desired temperature range. A processing circuit may use temperature and location information to adjust the heating or cooling of a portion of a battery, a battery as a whole, a portion of a battery module, or the battery module as a whole.

Batteries may be combined to form a battery module. Batteries may be electrically coupled in parallel and/or in series to form a battery module. The terminals of the batteries may be electrically coupled together to accomplish the parallel and/or serial coupling between the batteries. The terminals of the batteries may couple together to form a cathode terminal and an anode terminal of the battery module. The battery module provides and receives a current via the cathode terminal and the anode terminal of the battery module.

In an implementation, 95 batteries are coupled in series to form a battery module. Each battery provides a nominal 3.7

volts. Because the batteries are connected in series, the battery module may provide up to about 351 volts. The battery module may provide up to 200 amps of current.

The terminals of the batteries may be coupled together to form a manifold. A manifold includes one or more channels for flow of a medium (e.g., liquid) to transfer heat to or from the batteries of the battery module. For example, batteries may include terminals such as terminal **1210**. The terminals of such batteries may be coupled together to form one or more channels (e.g., channel **1212**) for the flow of a medium to transfer heat to and from the batteries. The terminals of the batteries so coupled together to provide one or more channels is referred to herein as a manifold. The terminals that form a manifold may include structures (e.g., fins, pins) for increasing the surface area of the manifold to facilitate heat transfer.

For example, batteries **1330** electrically couple together to form battery module **1130**. The terminals of batteries **1330** mechanically couple to form cathode terminal **1310** and anode terminal **1312** of battery module **1130**. Cathode terminals **1310** and anode terminals **1312** form manifold **1360**. Heat transfer medium **1350** flows through the cathode portion of manifold **1360**. Heat transfer medium **1352** flows through the anode portion of manifold **1360**. Heat transfer medium **1350** and heat transfer medium **1352** may transfer heat to or remove heat from batteries **1330**. Batteries **1330** and manifold **1360** may be in contact with and/or submersed in heat transfer medium **1340**. Heat transfer medium **1340** is contained in container **1320**. Heat transfer medium **1340** may circulate in container **1320**. Heat transfer medium **1340** transfers heat to and from manifold **1360** and/or batteries **1330**.

The terminals that form cathode terminal **1310** electrically couple to each other to provide a current to or from batteries **1330**. The terminals that form cathode terminal **1310** mechanically couple to provide a channel through which a heat transfer medium flows. The terminals that form anode terminal **1312** electrically couple to each other to provide a current to or from batteries **1330**. The terminals that form anode terminal **1312** mechanically couple to provide a channel through which a heat transfer medium flows. The flow of a heat transfer medium through the manifold transfers heat to or from the collectors of batteries **1330** via the terminals.

The terminals of batteries **1330**, whether cathode terminal **510** or anode terminal **512**, that form cathode terminal **1310** and anode terminal **1312** depends on whether batteries **1330** are connected in series or in parallel. The connection shown in FIG. **13** shows batteries **1330** connected in parallel. Because batteries **1330** are connected in parallel, the cathode terminals **510** of each battery **1330** couple to form cathode terminal **1310**, while anode terminals **512** of each battery **1330** couple to form anode terminal **1312**.

In an implementation in which batteries **1330** are coupled in series, anode terminal **512** of the battery that is first in the series forms anode terminal **1312**, while cathode terminal **510** of the battery that is last in the series forms cathode terminal **1310**. The connection of cathode terminal **510** to anode terminal **512** of a battery that is not at the start or end of the series (e.g., intermediate battery) required structure (e.g., conduit, pipe) to transport heat transport medium without shorting to the electrical connection of between other intermediate batteries. Intermediate batteries may have separate conduits for medium flow for the cathode terminal **510** and anode terminal **512** of each intermediate battery, so the series connection between intermediate batteries do not short each other out.

Heat transfer medium **1350** flows through the channel formed in cathode terminal **1310**. Heat transfer medium **1352** flows through the channel formed in anode terminal **1312**. Heat transfer mediums **1350**, **1352**, and **1340** include any liquid suitable for transferring heat. Heat transfer mediums **1350**, **1352**, and **1340** may include water and mineral oil. Heat transfer mediums **1350**, **1352**, and **1340** may include a medium that changes phase to transfer heat.

Battery **1330** may be any type of battery discussed above. Battery **1330** may include collectors that have a single tab per collector. Battery **1330** may include collectors that have two tabs per collector. Battery **1330** includes terminals with a channel for the flow of a heat transfer medium. The terminals of battery **1330** may include structures for increasing the surface area of the terminals. Battery **1330** may include temperatures sensors. The temperature sensors of batteries **1330** may report a detected temperature and the location of the temperature sensor in battery **1330** or the location of the battery **1330** in battery module **1130**.

Information related to the location of a temperature sensor may include a location in the battery, as discussed above, and a location in the battery module. For example, the location of a battery may be expressed as the column and row where the battery is positioned. The battery at row **0**, column **0** would be the battery on the lowest row of batteries and to the furthest left. The battery at row **1**, column **3** is the battery that is one row up from the lowest row and in the column that is the furthest to the right. As discussed above, a temperature sensor may be programed with its location information or the location information may be stored by a processing circuit and access using the temperature sensor identifier.

System **1100** of FIG. **11** regulates the temperature of the batteries **1330** of battery module **1130**. System **1100** includes heater **1110**, cooler **1112**, valve **1120**, **1122**, **1124**, and **1126**, pump **1114**, battery module **1130** and processing circuit **1160**.

A processing circuit includes any circuitry and/or electrical or electronic component for performing a function. A processing circuit may include circuitry that performs (e.g., executes) a stored program. A processing circuit may include a digital signal processor, a microcontroller, a microprocessor, an application specific integrated circuit, a programmable logic device, logic circuitry, state machines, MEMS devices, signal conditioning circuitry, memory, and/or communication circuitry.

A processing circuit may include passive electronic devices (e.g., resistors, capacitors, inductors) and/or active electronic devices (op amps, comparators, analog-to-digital converters, digital-to-analog converters, programmable logic, SRCs, transistors). A processing circuit may include data buses, output ports, input ports, timers, memory, and/or arithmetic units.

A processing circuit may provide and/or receive electrical signals whether digital and/or analog in form. A processing circuit may provide and/or receive digital information via a data bus using any protocol. A processing circuit may receive information, manipulate the received information, and provide the manipulated information. A processing circuit may analyze information and perform an operation in accordance with the analysis. A processing circuit may store information and retrieve stored information. Information received, stored, analyzed, and/or manipulated by the processing circuit may be used to perform a function, control a function, and/or to perform a stored program.

A processing circuit may control the operation and/or function of other circuits and/or components of a system such as electromechanical components (e.g., valve, cooler, pump). A processing circuit may receive status information regarding the operation of other components, perform calculations with respect to the status information, and provide commands (e.g., instructions) to one or more other components. A processing circuit may command another component to start operation, continue operation, alter operation, suspend operation, or cease operation. Commands and/or status may be communicated between a processing circuit and other circuits and/or components via any type of bus (e.g., SPI bus) including any type of data/address bus.

Valve **1120-1126** permits a flow of a medium (e.g., liquid) along a path or blocks the flow of medium along the path. Valve **1120-1126** may permit a flow of medium at a specified rate of flow. Valve **1120-1126** may be controlled by an electrical signal. A processing circuit may provide the signal for controlling valves **1120-1126**.

Heater **1110** may prepare (e.g., condition) a medium for transferring heat to battery module **1130**. A cooler may prepare a medium for transferring heat from battery module **1130**.

Pump **1114** may control the flow of medium in the fluid circuits of system **1100** and in the manifold of battery module **1130**. Pump **1114** may push or pull a flow of medium into or out of manifold **1360** of battery module **1130**. Pump **1114** may circulate heat transfer medium **1340** in container **1320**. Pump **1114** may establish a rate of flow of a medium. Pump **1114** may increase, decrease, or maintain a rate of flow of a medium. Pump **1114** may provide a laminar flow of medium.

For example, processing circuit **1160** receives information from the temperature sensors of battery module **1130**. Processing circuit **1160** may use the temperature sensor identifier to access a database that stores the location of each temperature sensor in battery module **1130** and respective battery **1330**. Processing circuit **1160** may use the temperature information from the temperature sensors and the location information to control heater **1110**, cooler **1112**, valve **1120**, valve **1122**, valve **1124**, valve **1126**, and pump **1114**. Processing circuit **1160** may control the components of system **1100** to maintain the temperature of battery module **1130** at a particular temperature. Processing circuit **1160** may maintain the temperature of battery module **1130** within a range of temperatures.

Temperature sensors may also be positioned in heat transfer medium **1340**, in container **1320**, on container **1320**, on an outside surface of container **1320**, inside a channel of manifold **1360**, or in a fluid circuit of system **1100**. Temperature systems may be positioned before or after heater **1110**, cooler **1112**, valves **1120-1126**, pump **1114**, and battery module **1130**. Processing circuit **1160** may use this temperature information when adjusting the components of system **1100** to control the temperature of battery module **1130**.

To transfer heat to battery module **1130**, processing circuit **1160** may open valve **1120** and valve **1124**, and close valve **1122** and valve **1126** to steer medium through heater **1110** before it enters battery module **1130**. To transfer heat from battery module **1130**, processing circuit **1160** may open valve **1122** and valve **1126**, and close valve **1120** and valve **1124** to steer medium through cooler **1112** before it enters battery module **1130**. Processing circuit **1160** may alternately open and close valves to maintain the temperature of battery module **1130**.

The foregoing description discusses implementations (e.g., embodiments), which may be changed or modified without departing from the scope of the present disclosure as defined in the claims. Examples listed in parentheses may be used in the alternative or in any practical combination. As used in the specification and claims, the words 'comprising', 'comprises', 'including', 'includes', 'having', and 'has' introduce an open-ended statement of component structures and/or functions. In the specification and claims, the words 'a' and 'an' are used as indefinite articles meaning 'one or more'. While for the sake of clarity of description, several specific embodiments have been described, the scope of the invention is intended to be measured by the claims as set forth below. In the claims, the term "provided" is used to definitively identify an object that not a claimed element but an object that performs the function of a workpiece. For example, in the claim "an apparatus for aiming a provided barrel, the apparatus comprising: a housing, the barrel positioned in the housing", the barrel is not a claimed element of the apparatus, but an object that cooperates with the "housing" of the "apparatus" by being positioned in the "housing".

The location indicators "herein", "hereunder", "above", "below", or other word that refer to location in the specification, whether specific or general, shall be construed to refer to any location in the specification whether the location is before or after the location indicator.

Methods described herein are illustrative examples, and are not intended to require or imply that any particular process of any embodiment be performed in the order presented. Words such as "thereafter," "then," "next," etc. are not intended to limit the order of the processes, and these words are instead used to guide the reader through the description of the methods.

What is claimed is:

1. A rechargeable battery comprising:

a plurality of collectors, each collector includes a tab, the plurality of the collectors divided into a first group and a second group;

a first terminal and a second terminal, each terminal formed of an electrically and thermally conductive material, each terminal has a length, a first end and a second end; wherein:

each collector of the first group is positioned between two collectors of the second group or to a side of one collector of the second group;

each tab of the first group electrically couples to the first terminal; and

each tab of the second group electrically couples to the second terminal;

the plurality of collectors provides a current via the first terminal and the second terminal; and

at least one of the first terminal and the second terminal includes a channel formed in an interior and along the length of the material that forms the at least one terminal, the channel is open only at the first end and the second end of the at least one terminal, the channel is adapted to receive a flow of a first heat transfer medium, the channel is adapted to contain the flow of the first heat transfer medium inside the channel as it flows between the first end and the second end, the flow of the first heat transfer medium through the channel provides heat to or removes heat from the plurality of collectors coupled to the at least one terminal, the least one terminal is adapted to carry the current via the conductive material that surrounds the channel.

2. The rechargeable battery of claim **1** wherein the first terminal and the second terminal include at least one of fins and pins to increase a surface area of the first terminal and the second terminal.

3. The rechargeable battery of claim **1** wherein the tab of any collector of the first group does not overlap the tab of any collector of the second group.

4. The rechargeable battery of claim **1** wherein the current flows along an entire width of the tab of each collector.

5. The rechargeable battery of claim **1** wherein the current flows through each tab of the first group via the first terminal and through each tab of the second group via the second terminal.

6. The rechargeable battery of claim **1** further comprising a container and a second heat transfer medium wherein:
- the rechargeable battery is positioned in the container;
- the second heat transfer medium is contained in the container around the rechargeable battery; and
- the second heat transfer medium is adapted to transfer heat to and remove heat from the rechargeable battery.

7. The rechargeable battery of claim **1** further comprising a container and a second heat transfer medium wherein:
- the rechargeable battery is positioned in the container;
- the second heat transfer medium is contained in the container around the rechargeable battery; and
- the second heat transfer medium is adapted to transfer heat to and remove heat from the at least one of the first terminal and the second terminal.

8. The rechargeable battery of claim **7** wherein the second heat transfer medium comprises mineral oil whereby the second heat transfer medium does not electrically connect the first terminal and the second terminal.

9. The rechargeable battery of claim **1** further comprising a temperature sensor in or on at least one of the first terminal and the second terminal.

10. A rechargeable battery comprising:
- a plurality of anode collectors, each anode collector includes a first tab;
- a plurality of cathode collectors, each cathode collector includes a second tab;
- a first terminal and a second terminal, each terminal formed of an electrically and thermally conductive material, each terminal has a length, a first end and a second end; wherein:
  - each anode collector is positioned between two cathode collectors or to a side of one cathode collector;
  - each first tab of the plurality of anode collectors electrically couples to the first terminal;
  - each second tab of the plurality cathode collectors electrically couples to the second terminal;

  - the plurality of anode collectors and the plurality of cathode collectors provide a current via the first tab, the second tab, the first terminal and the second terminal; and
  - at least one of the first terminal and the second terminal includes a channel formed in an interior and along the length of the material that forms the at least one terminal, the channel is open only at the first end and the second end of the at least one terminal, the channel is adapted to receive a flow of a first heat transfer medium, the channel is adapted to contain the flow of the first heat transfer medium inside the channel as it flows between the first end and the second end, the flow of the first heat transfer medium through the channel provides heat to or removes heat from the plurality of anode collectors or cathode collectors coupled to the at least one terminal respectively, the least one terminal is adapted to carry the current via the conductive material that surrounds the channel.

11. The rechargeable battery of claim **10** wherein at least one of the first terminal and the second terminal further includes a plurality of fins.

12. The rechargeable battery of claim **11** wherein a spacing between the fins provides between 20 and 30 fins per inch.

13. The rechargeable battery of claim **11** wherein a spacing between the fins provides between 5 and 18 fins per inch.

14. The rechargeable battery of claim **11** wherein the fins are V-shaped.

15. The rechargeable battery of claim **10** wherein at least one of the first terminal and the second terminal further includes a plurality of pins.

16. The rechargeable battery of claim **15** wherein the pins are cylindrical.

17. The rechargeable battery of claim **10** further comprising a temperature sensor in or on at least one of the first terminal and the second terminal.

18. The rechargeable battery of claim **10** further comprising a container and a second heat transfer medium wherein:
- the rechargeable battery is positioned in the container;
- the second heat transfer medium is contained in the container around the rechargeable battery; and
- the second heat transfer medium is adapted to transfer heat to and remove heat from the first terminal and the second terminal.

19. The rechargeable battery of claim **18** wherein the second heat transfer medium comprises mineral oil whereby the second heat transfer medium does not electrically connect the first terminal and the second terminal.

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